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RESEARCH MEMORANDUM

AERODYNAMIC STUDY OF A WING-FUSELAGE COMBINATION EMPLOYING A WING SWEPT BACK 63°. - INVESTIGATION OF A LARGE-SCALE MODEL AT LOW SPEED

By Gerald M. McCormack and Walter C. Walling

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Moffett Field, Calif.

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

RESEARCH MEMORANDUM

AERODYNAMIC STUDY OF A WING-FUSELAGE COMBINATION EMPLOYING A WING SWEPT BACK 63°.- INVESTIGATION OF A LARGE-SCALE MODEL AT LOW SPEED

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SUMMARY

An investigation has been made to determine the low-speed characteristics at high Reynolds numbers of a 63° swept-back wing. Aerodynamic characteristics are presented for the wing alone and for the wing-fuselage combination.

The wing exhibited longitudinal instability at a lift coefficient of about 0.5. The maximum effective dihedral was about 18°, and the wing had neutral directional stability up to a lift coefficient of about 0.6. The fuselage had negligible effect on lift and pitching moments; it did, however, decrease the dihedral effect and contributed a destabilizing increment of about -0.0012 to the directional stability of the wing.

The relationships between the force and moment characteristics and flow conditions existing over the wing are discussed in the report.

INTRODUCTION

The theory developed in reference 1 indicates that aircraft employing wings of high sweepback and high aspect ratio should be capable of efficient flight $(L/D \cong 10)$ at moderate supersonic Mach numbers. To provide information necessary for the design of such an airplane, a possible configuration for a transport-type airplane suitable for flight at speeds up to 1.5 Mach number is undergoing study in the research facilities of the Ames Aeronautical Laboratory.

The design incorporates a wing with the leading edge swept back 63°, an aspect ratio of 3.5, and a taper ratio of 0.25, with a fuselage of fineness ratio 12.5.

The aerodynamic characteristics of this configuration are being examined over a large range of Mach numbers and Reynolds numbers. This report presents the aerodynamic characteristics at low speed and high Reynolds number as determined in the Ames 40- by 80-foot wind tunnel.

COEFFICIENTS AND SYMBOLS

The data are presented in the form of standard NACA coefficients and symbols, as defined in figure 1 and the following tabulation. All forces and moments were computed about the stability axes with the origin located in the plane of symmetry of the model at the same vertical and fore-and-aft location as the quarter-chord point of the mean aerodynamic chord. (The stability axes are a system of axes in which the normal (lift) axis lies in the plane of symmetry and is perpendicular to the relative wind; the longitudinal (drag) axis lies in the plane of symmetry and is perpendicular to the normal axis; and the lateral axis is perpendicular to the plane of symmetry.)

C_L lift coefficient $\left(\frac{\text{lift}}{qS}\right)$

C_D drag coefficient $\left(\frac{\text{drag}}{qS}\right)$

C_m pitching-moment coefficient $\left(\frac{\text{pitching moment}}{qS\bar{c}}\right)$

C_l rolling-moment coefficient $\left(\frac{\text{rolling moment}}{qSb}\right)$

c_l section lift coefficient

C_n yawing-moment coefficient $\left(\frac{\text{yawing moment}}{qSb}\right)$

C_Y side-force coefficient $\left(\frac{\text{side force}}{qS}\right)$

C_{L_α} rate of change of lift coefficient with angle of attack, per degree

C_{l_β} rate of change of rolling-moment coefficient with angle of sideslip, per degree

C_{n_β} rate of change of yawing-moment coefficient with angle of sideslip, per degree

a.c. aerodynamic center location, measured in percent of the mean aerodynamic chord from the leading edge

R Reynolds number

q dynamic pressure, pounds per square foot

α angle of attack, degrees

β angle of sideslip, degrees

S wing area, square feet

b wing span measured perpendicular to the plane of symmetry, feet

$\bar{c}$ mean aerodynamic chord

$$\left(\frac{\int_0^{b/2} c^2 dy}{\int_0^{b/2} c dy}\right), \text{ feet}$$

c local chord measured parallel to plane of symmetry, feet

y spanwise coordinate, feet

A aspect ratio $\left(\frac{b^2}{S}\right)$

Λ angle of sweep of the wing leading edge, degrees

Γ_e effective dihedral, degrees

MODEL AND TESTS

The geometric characteristics and over-all dimensions of the model are shown in figure 2. The wing has 63° sweepback of the leading edge, an aspect ratio of 3.5, a taper ratio of 0.25, and no twist. The airfoil is an NACA 64A006 section parallel to the plane of symmetry. The fuselage has a fineness ratio of 12.5 and a circular cross section. The wing was mounted on the fuselage center line with zero incidence. Based on a wing loading of 50 pounds per square foot and a design weight of 40,000 pounds, the model tested in the 40- by 80-foot wind tunnel is about half scale. Photographs of the wing and the wing-fuselage combination mounted in the wind tunnel are shown in figures 3 and 4.

The wing was tested alone and in combination with the fuselage. Six-component force and moment data were obtained through an angle-of-attack range at each of several angles of sideslip. The data were obtained at a dynamic pressure of 25 pounds per square foot (a Reynolds number of 8×10^6 based upon the mean aerodynamic chord of 8.64 ft).

The wind-tunnel data have been corrected for air-stream inclination and for tunnel-wall effects. A brief analysis indicated that the tunnel-wall corrections were approximately the same for unswept and swept wings of the relatively small size under consideration. Therefore, the standard corrections for an unswept wing of the same area and span were applied as follows:

$$\Delta\alpha = 0.48\ C_L$$

$$\Delta C_D = 0.0084\ {C_L}^2$$

No corrections have been applied for the drag and interference of the struts. With the exception of the effect on the drag results, these corrections are felt to be small and negligible. The effect on drag is of the order of $\Delta C_D = 0.008$ at zero lift, but is not known with sufficient accuracy to warrant application. This should be borne in mind when the drag data are analyzed in terms of flight characteristics.

RESULTS

The aerodynamic characteristics of the wing and the wing-fuselage combination are presented in figures 5 and 6, respectively. A summary of the longitudinal characteristics at zero sideslip follows:

	Wing	Wing-fuselage combination
[1]C_{L_α}, per degree	0.042	0.047
[1]a.c. location, percent $\bar{c}$	38	38
$C_{L_{max}}$	1.26	1.32

$\Delta C_{D_{min}}$ due to fuselage = 0.0045

The lateral-stability parameters of the wing and the wing-fuselage combination are indicated in figure 7. A summary of the lateral-stability characteristics follows:

	Wing	Wing-fuselage combination
[2]$\partial C_{l_\beta}/\partial C_L$	−0.006	−0.005
$C_{l_{\beta_{max}}}$	$-0.0036(\Gamma_e \cong 18^\circ)$	$-0.0030(\Gamma_e \cong 15^\circ)$
[2]$\partial C_{n_\beta}/\partial C_L$	0	0

[2]ΔC_{n_β} due to fuselage = −0.0012

[1]These are average values in the low-lift range (i.e., between $C_L = 0$ and $C_L = 0.2$).

[2]These are average values obtained between $C_L = 0$ and $C_L = 0.6$.

DISCUSSION

Experimentally obtained characteristics of the wing are compared with characteristics predicted by the method of Weissinger (reference 2) in figure 8 and in the following tabulation:

	Experimental[1]	Theoretical
C_{L_α}, per degree	0.042	0.041
a.c. location, percent $\bar{c}$	38	39

Good agreement is obtained in the low-lift range. Above a lift coefficient of about 0.2, however, the characteristics deviate markedly from the initial trends in a manner which is typical of highly swept wings having a relatively high aspect ratio. Observations of tufts indicated that these deviations were attributable to flow separation which occurred first near the tips and then spread inward.

An accurate prediction of the occurrence of separation over a swept-back wing is extremely difficult due to three-dimensional flow, Reynolds number, etc. Hence, any method that will give a reasonable indication of the occurrence of separation is of considerable value. In reference 3, it was reasoned that separation over an oblique wing could be predicted to occur when the lift coefficient, based on the component of velocity normal to the leading edge, exceeded the two-dimensional maximum lift coefficient of the airfoil section (i.e., $C_{L_{sep}} = c_{l_{max}} \cos^2\Lambda$). Based on an estimated two-dimensional maximum lift coefficient of about 1.3 (airfoil section perpendicular to the leading edge about 11 percent thick), the wing might be expected to exhibit separation at $C_L = 0.26$. This value agrees reasonably well with the experimental results, which showed that separation occurred at a lift coefficient of about 0.2.

The nonlinear deviations which followed the occurrence of separation at 0.2 lift coefficient result from the peculiar stalling characteristics of swept wings (described in detail in reference 4). If the analysis of reference 4 is used to interpret the characteristics of the present wing, it would appear that turbulent

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[1]See footnote 1, page 5.

separation occurs at a lift coefficient of about 0.2. The drag begins to rise rapidly while the pitching moments become more negative due to the rearward shift of center of pressure of the sections suffering separation. As a result the aerodynamic center shifts rearward to about 52 percent $\bar{c}$.

Again, following the analysis of reference 4, before turbulent separation can spread to an appreciable extent, leading-edge separation spreads suddenly along the leading edge of the wing. In this case, the effect of leading-edge separation becomes appreciable at a lift coefficient of about 0.5. As leading-edge separation occurs at a section, the suction peak is lost and, consequently, lift is lost. Since leading-edge separation starts at the tip and travels inward and, hence, forward with increase in angle of attack, the center of load moves forward, and thus causes longitudinal instability. (The aerodynamic center moves forward to a position about 25 percent $\bar{c}$ ahead of the leading edge of the mean aerodynamic chord.) This is accompanied by a decrease of the lift-curve slope and a continuation of the rapid drag rise. As shown by figure 8, above a lift coefficient of 0.55 the drag variation approaches that of a flat plate.

The lateral characteristics reflect the behavior evidenced in the lift, drag, and pitching-moment characteristics. In figure 7, it is seen that, in the low-lift range, C_{l_β} varies approximately linearly with lift coefficient, and C_{n_β} does not change appreciably with lift coefficient. The trends set up in the unseparated flow regime are only slightly affected by the first appearance of separation. Coincident with the reversal of the pitching-moment curve, the C_{l_β} curve reverses direction and falls off rapidly, and the C_{n_β} curve breaks in the positive direction.

CONCLUDING REMARKS

An investigation has been made of the low-speed aerodynamic characteristics of a large-scale 63° swept-back wing and wing-fuselage combination.

In the low-lift range, characteristics predicted by the method of Weissinger agree very well with the experimentally obtained characteristics. However, at a lift coefficient of about 0.2, separation occurred over the wing. Above this lift coefficient, the drag increased at a rapid rate and the wing became first very stable longitudinally and then extremely unstable. Longitudinal instability occurred at a lift coefficient of about 0.5.

The maximum effective dihedral of the wing was approximately 18° at a lift coefficient of about 0.6. The wing exhibited neutral directional stability up to this lift coefficient.

The fuselage had negligible effect on lift and pitching moments; it did, however, decrease the dihedral effect about 3° and contributed a destabilizing increment of about −0.0012 to the directional stability of the wing.

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National Advisory Committee for Aeronautics,
Moffett Field, Calif.

REFERENCES

1. Jones, Robert T.: Estimated Lift-Drag Ratios at Supersonic Speed. NACA TN No. 1350, 1947.

2. DeYoung, John: Theoretical Additional Span Loading Characteristics of Wings with Arbitrary Sweep, Aspect Ratio, and Taper Ratio. NACA TN No. 1491, 1947.

3. Jones, Robert T.: Effects of Sweepback on Boundary Layer and Separation. NACA TN No. 1402, 1947.

4. McCormack, Gerald M. and Cook Woodrow L.: A Study of Stall Phenomena on a 45° Swept-Forward Wing. NACA TN No. 1797, 1949.

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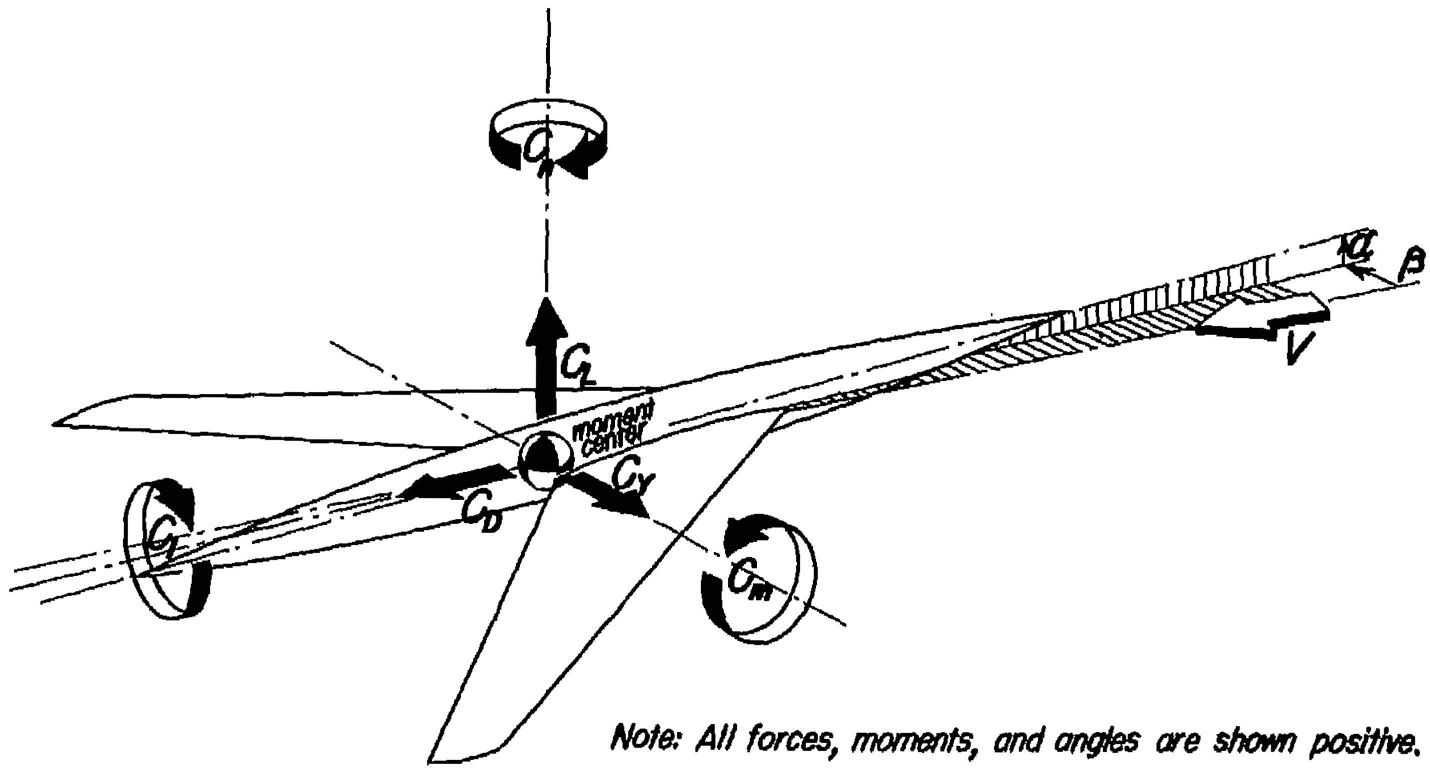

Figure 1.- Standard NACA sign convention.

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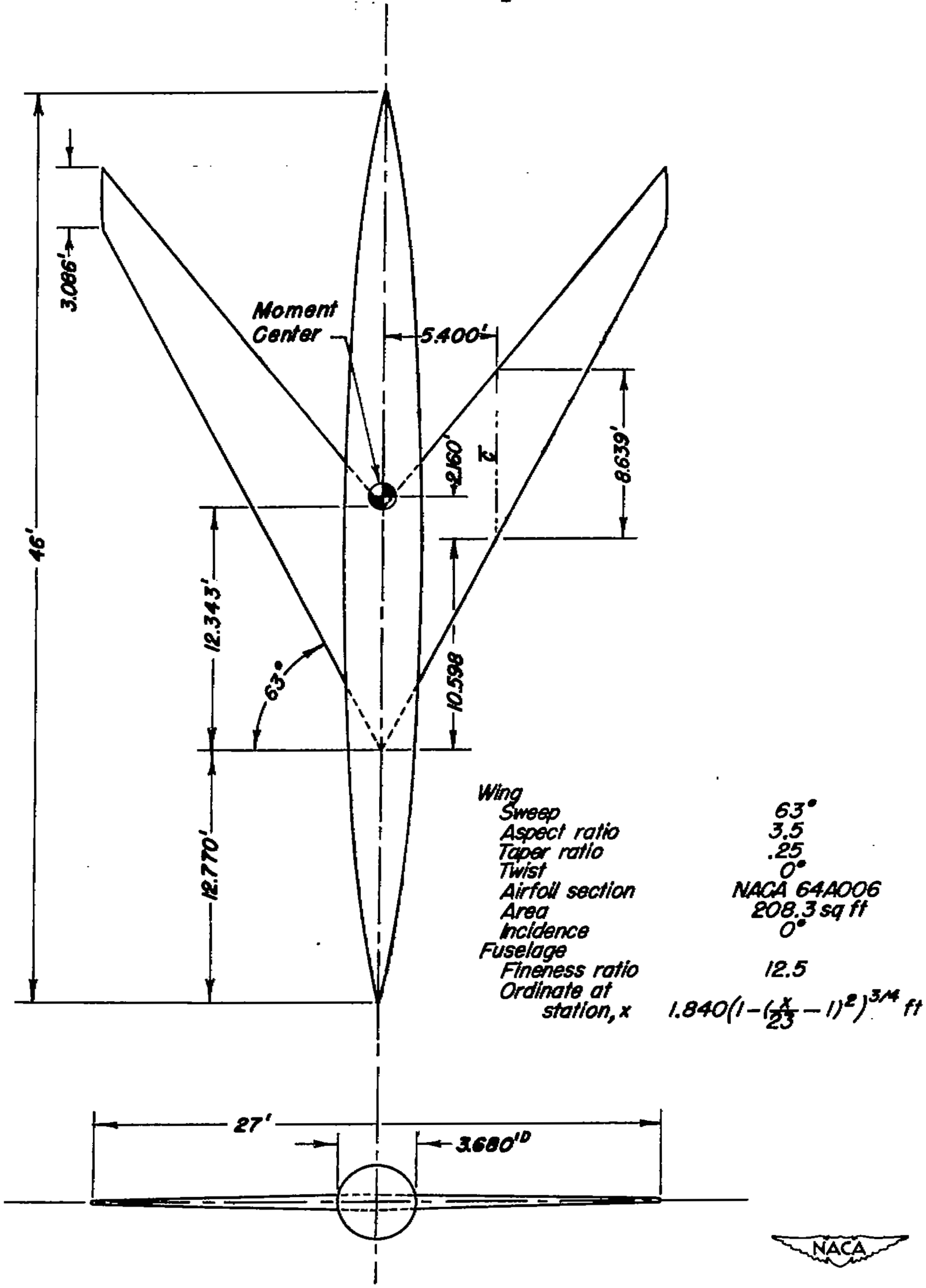

Figure 2.-Geometric characteristics of 63° swept-back wing plus fuselage.

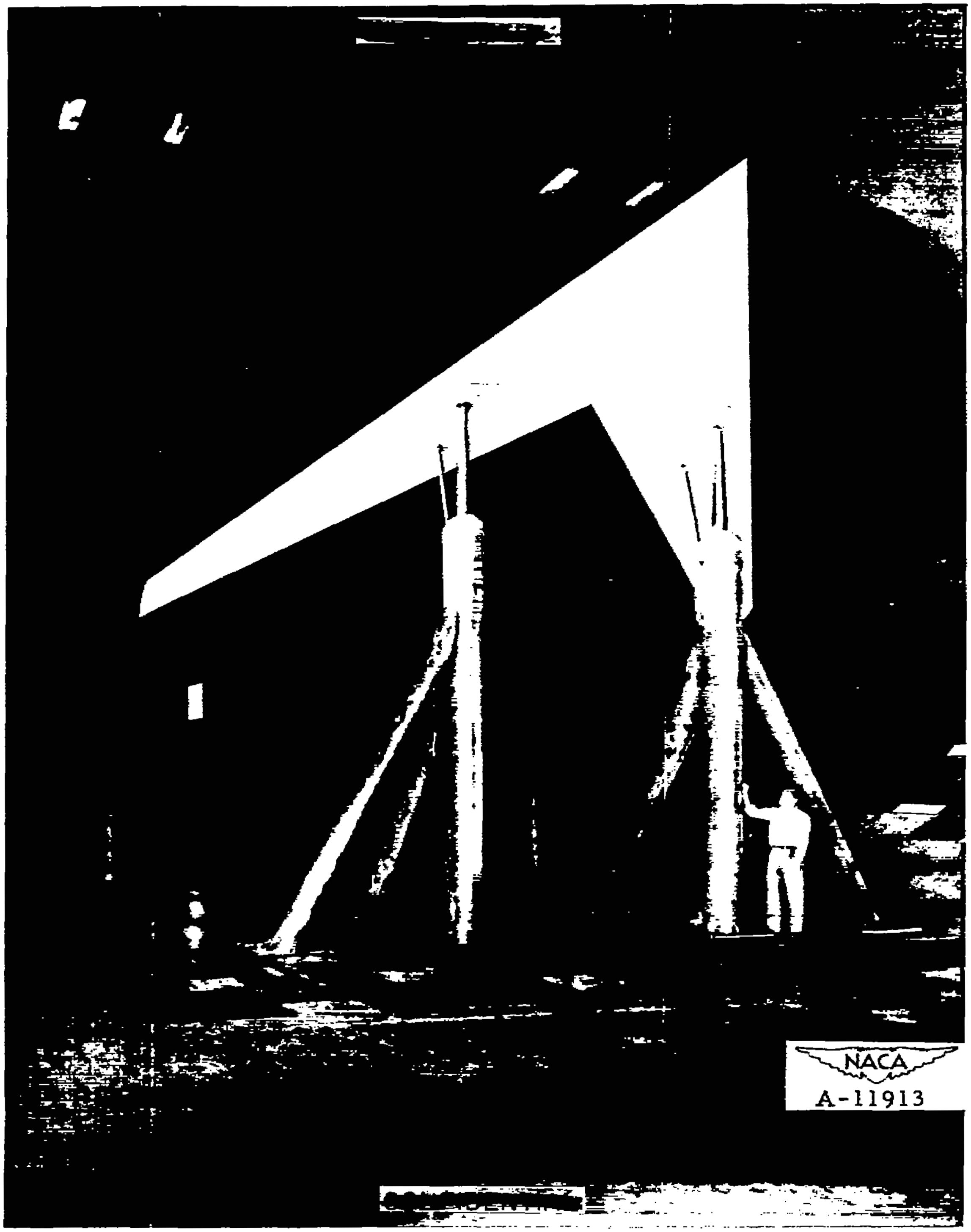

Figure 3.— Photograph of 63° swept-back wing mounted in Ames 40- by 80-foot wind tunnel.

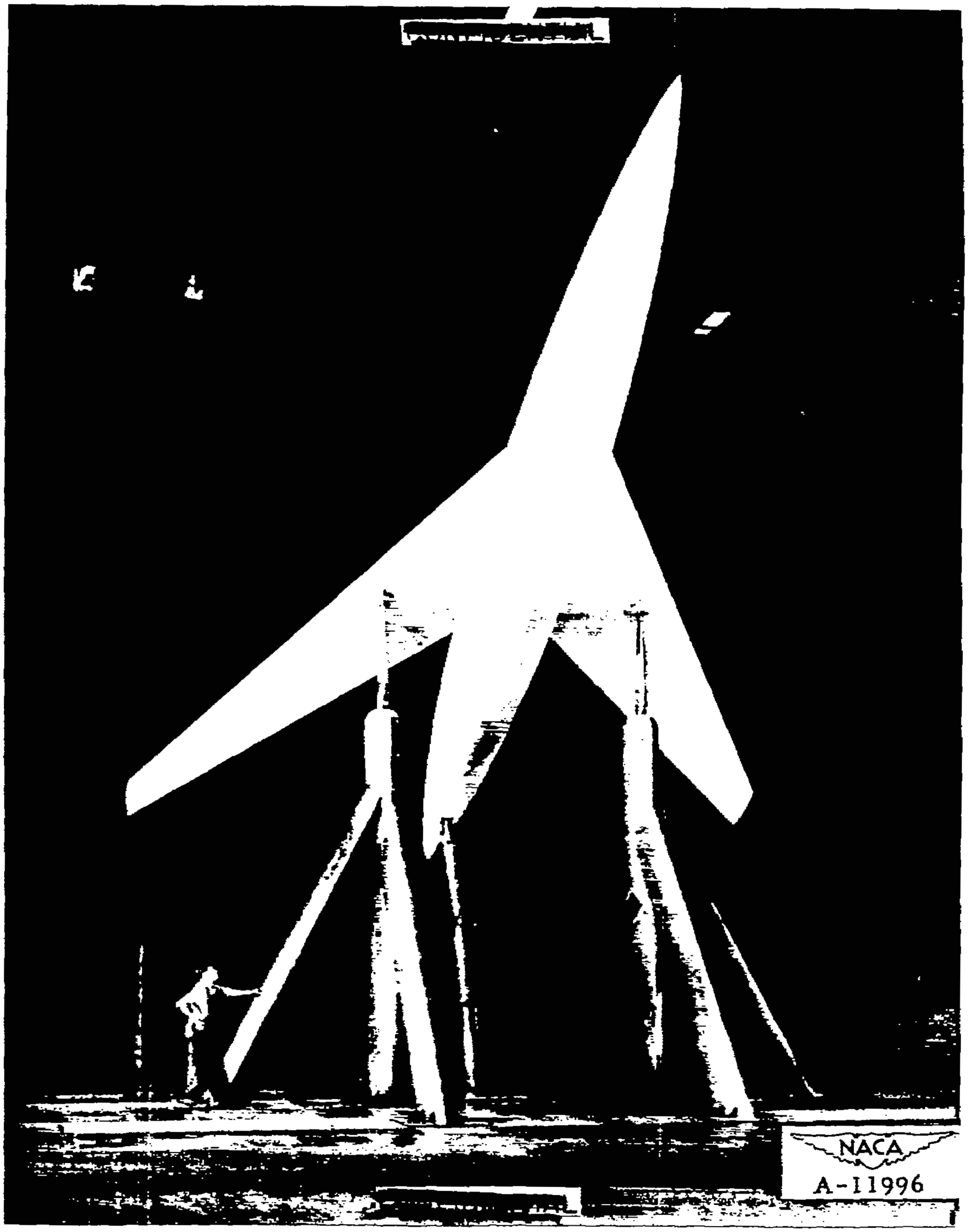

Figure 4.— Photograph of 63° swept-back wing-fuselage combination mounted in Ames 40- by 80-foot wind tunnel.

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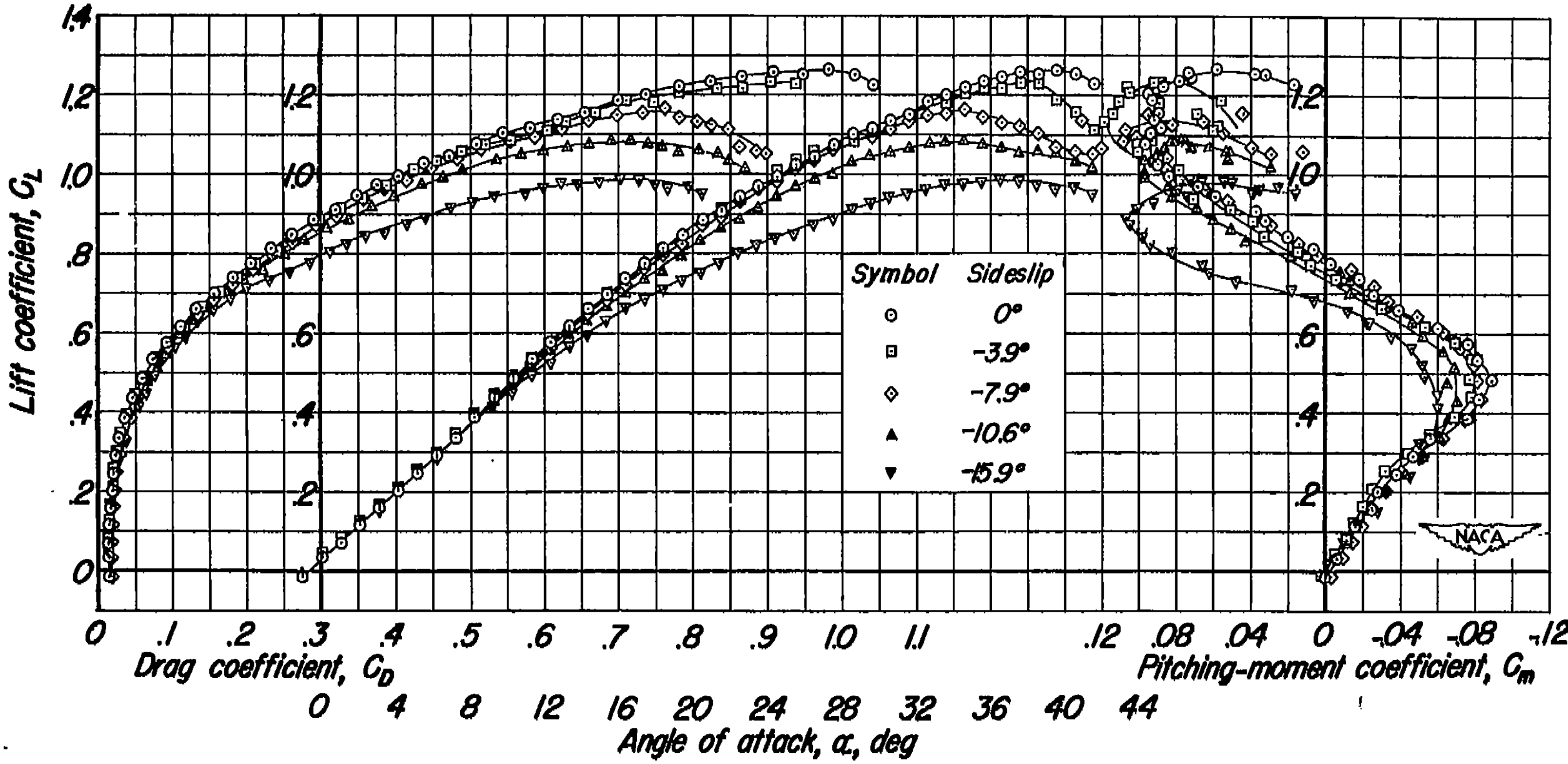

(a) C_L vs C_D, α°, C_m

Figure 5.- Aerodynamic characteristics of 63° swept-back wing at various angles of sideslip.

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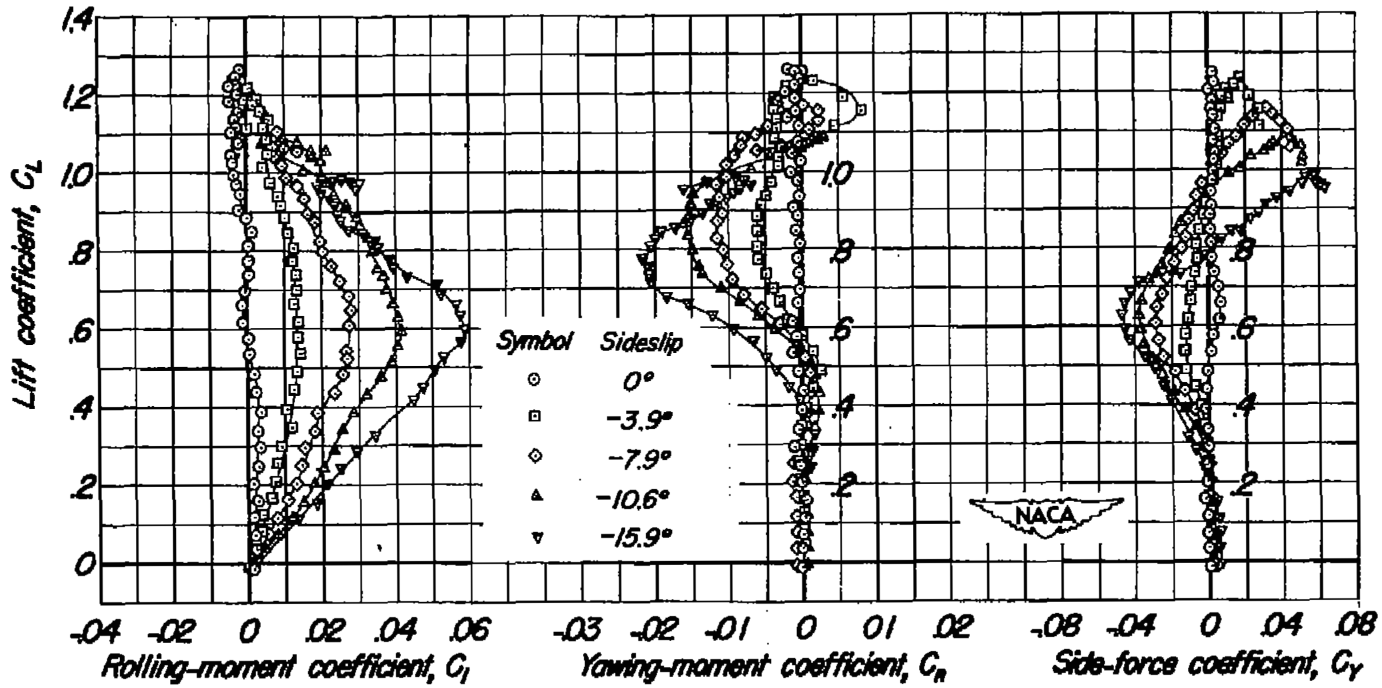

(b) C_L vs C_l, C_n, C_Y

Figure 5.- Concluded.

[redacted]

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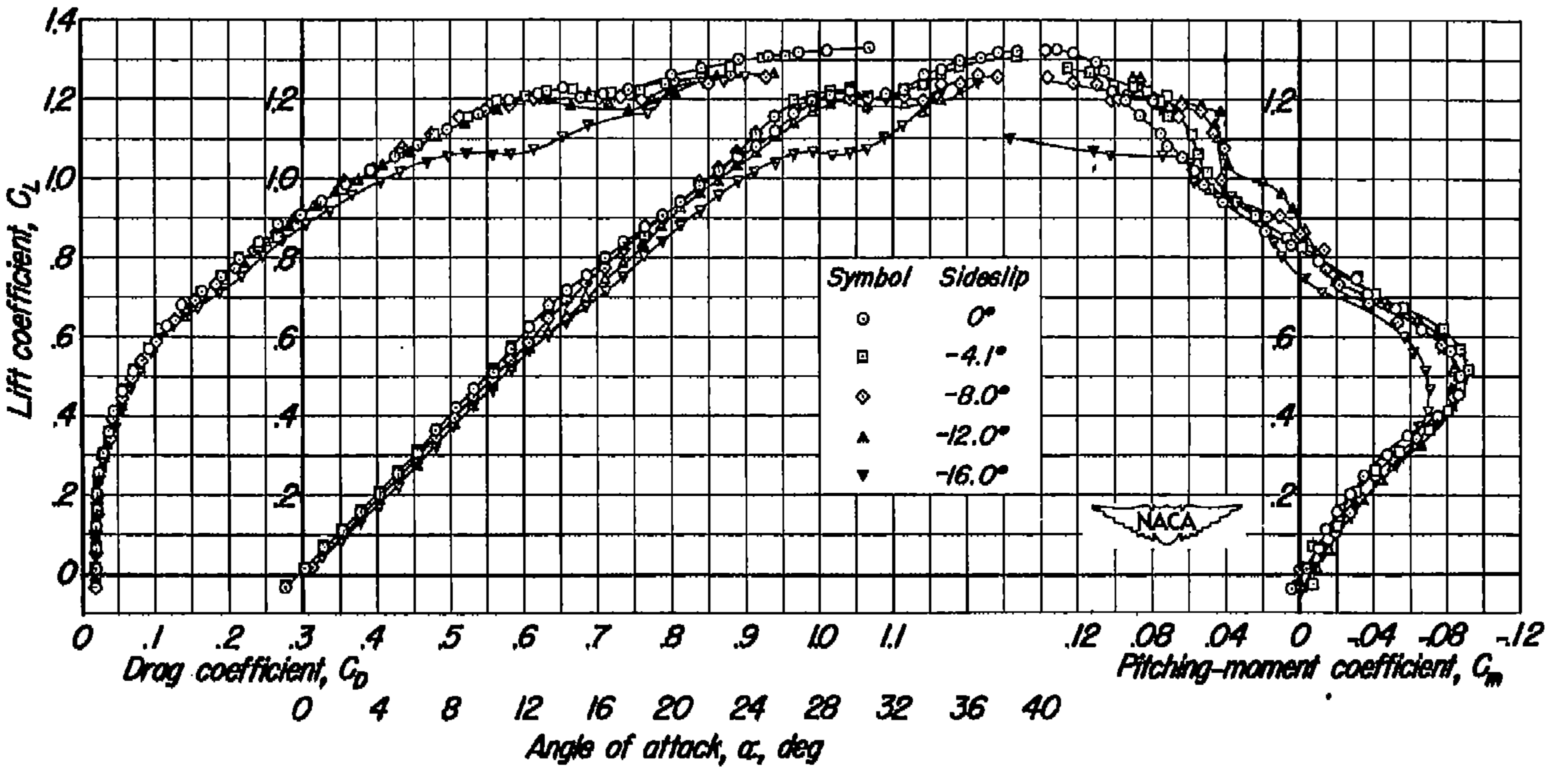

(a) C_L vs C_D, α, C_m

Figure 6.- Aerodynamic characteristics of 63° swept-back wing plus fuselage at various angles of sideslip.

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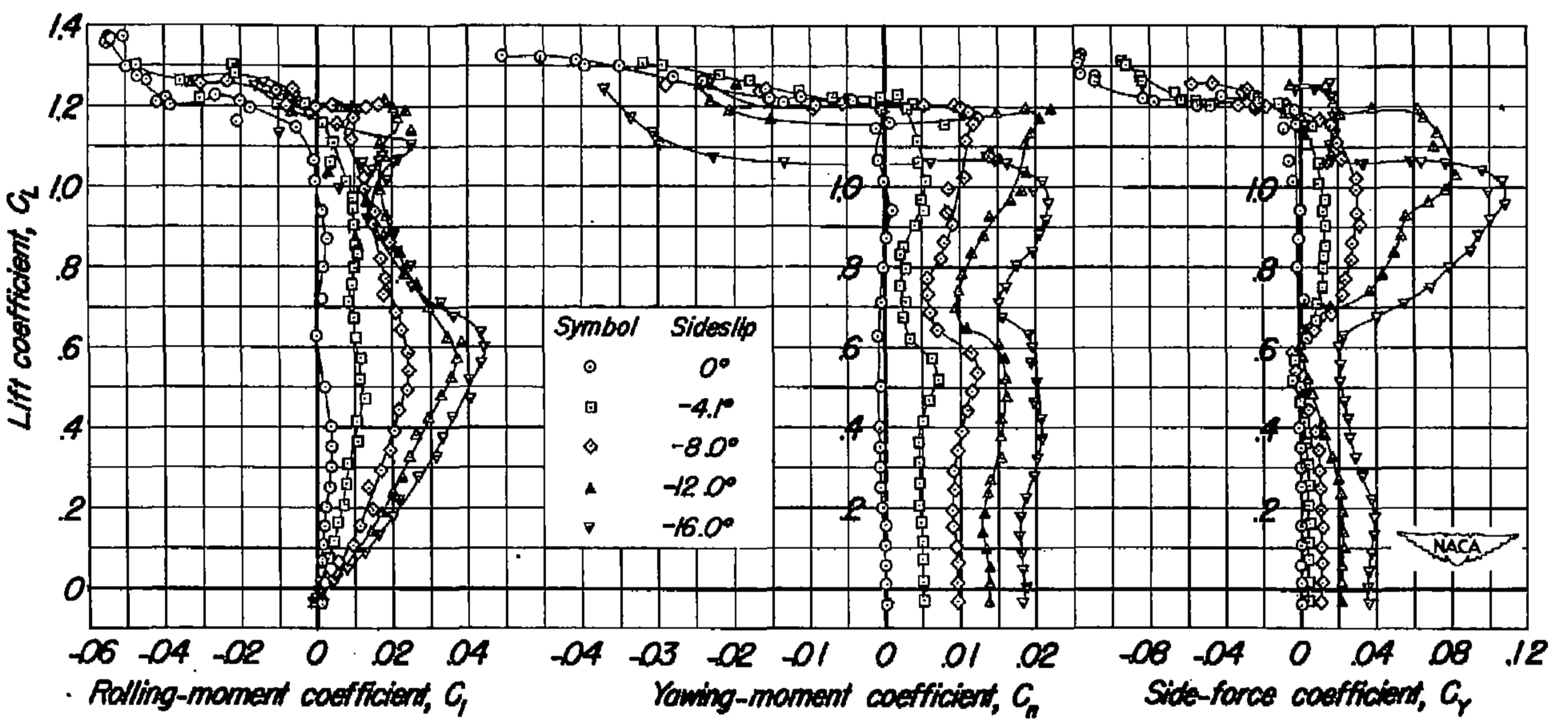

(b) C_L vs C_l, C_n, C_Y

Figure 6.- Concluded.

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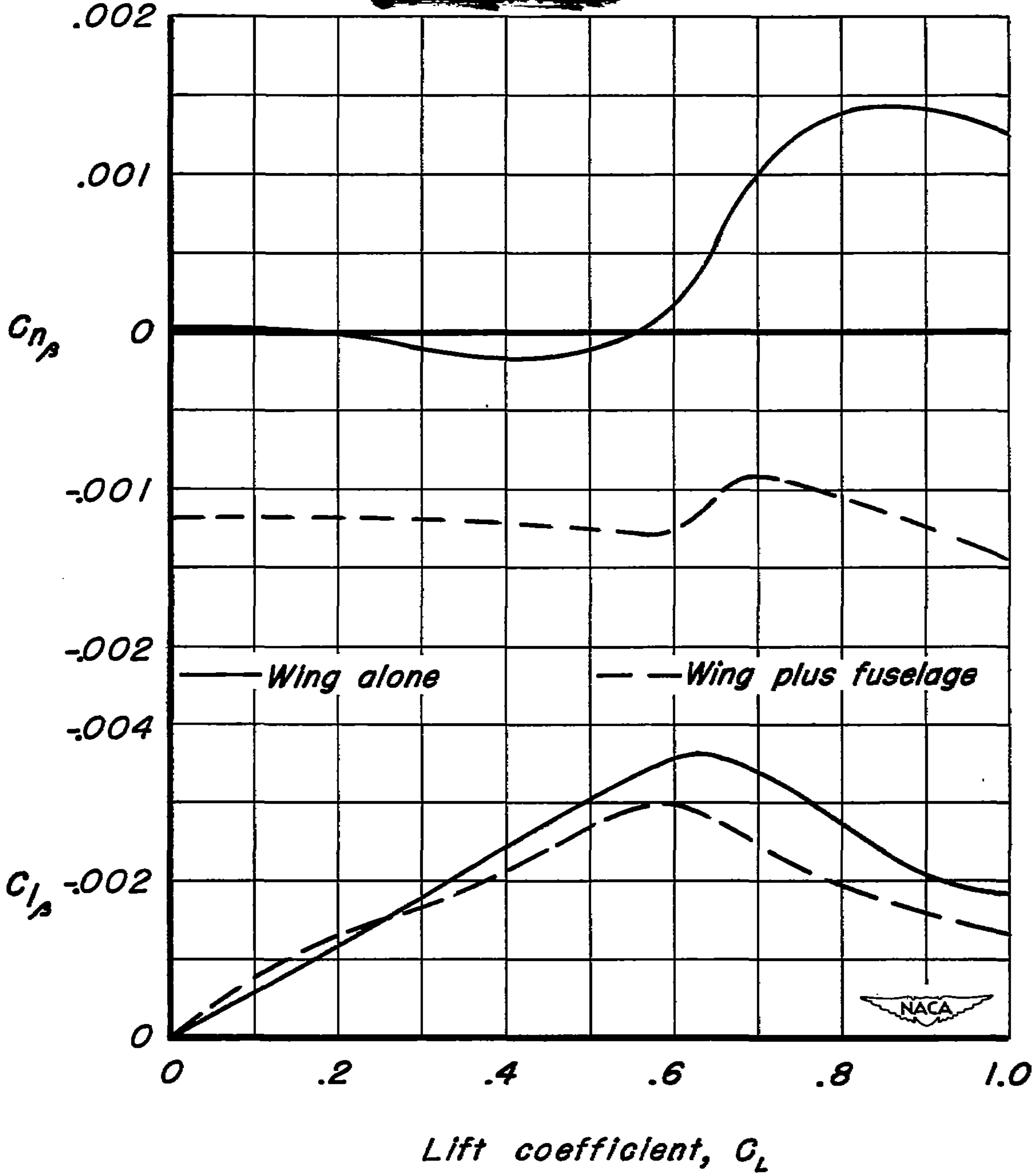

Figure 7.- Effect of fuselage on lateral characteristics of 63° swept-back wing.

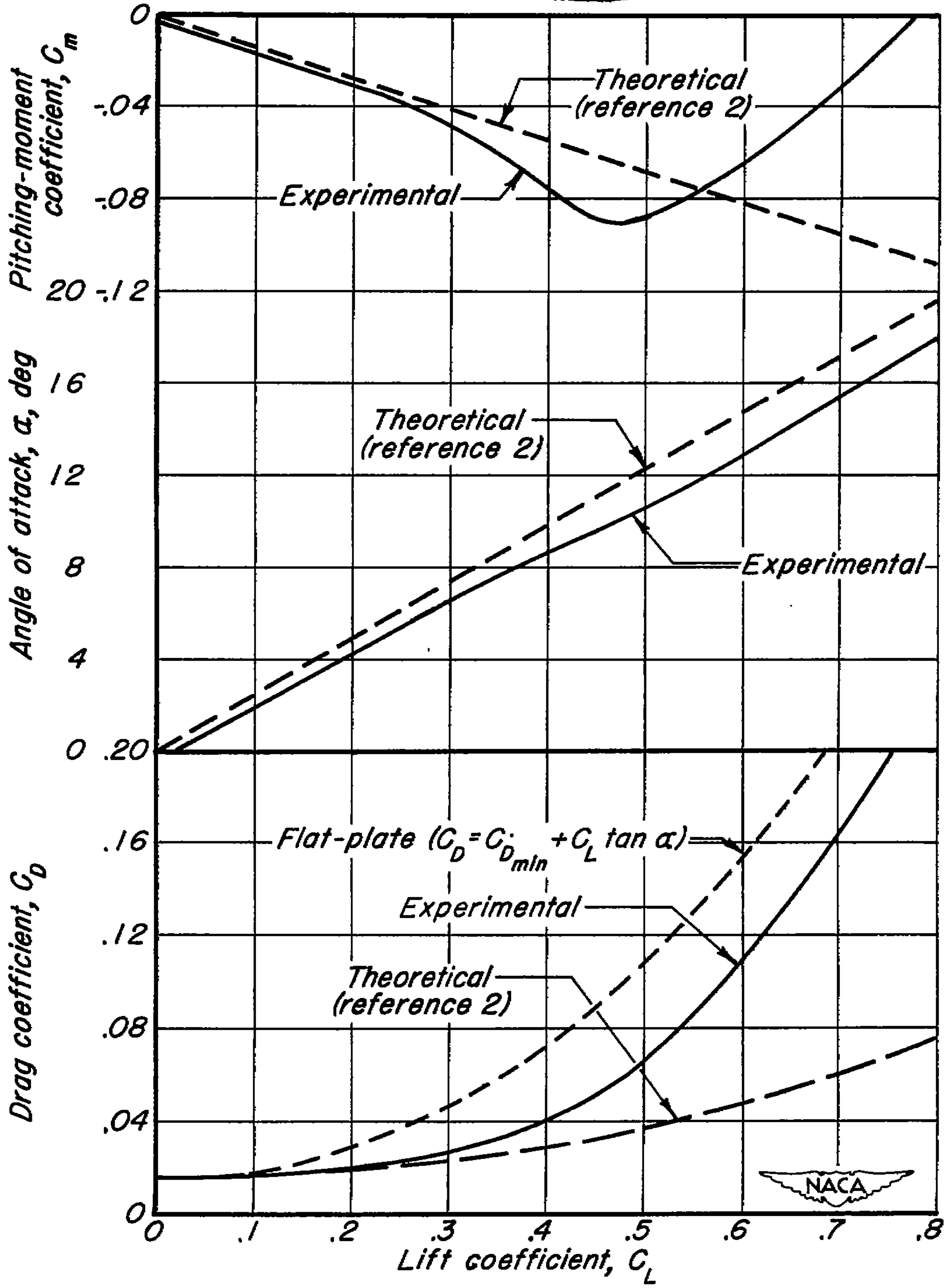

Figure 8.– Comparison between experimental and theoretical longitudinal characteristics of 63° swept-back wing.

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